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NEW TREND OF AUTOMOBILE ASPECTS ON MHD OF HYBRID NANOFLUID FLOW OVER A POROUS STRETCHING CYLINDER: A NUMERICAL STUDY

Gunisetty Ramasekhar[a]*, Y. Rameswara Reddy[b#], Sura Sreenivasulu[c], Shaik Jakeer[d], Seethi Reddy Reddisekhar Reddy[e], Sangapatnam Suneetha[f], T. Aditya Sai Srinivas[g], Ashok Sarabu[h]

[a]*Department of Mathematics, Rajeev Gandhi Memorial College of Engineering and Technology (Autonomous), Nandyal – 518501, Andhra Pradesh, India*
[b]*Department of Mechanical Engineering, JNTUACE, Pulivendula – 516390, Andhra Pradesh, India*
[c]*Department of Chemistry, SVR Engineering College, Ayyaluru Meta, Nandyal – 518501, Andhra Pradesh, India*
[d]*School of Technology, The Apollo University, Chittoor, Andhra Pradesh 517127, India*
[e]*Department of Mathematics, Koneru Lakshmaiah Education Foundation, Bowrampet, Hyderabad, Telangana – 500043, India*
[f]*Department of Applied Mathematics Yogi Vemana University Kadapa – 516003, Andhra Pradesh, India*
[g]*Department of Computer Science & Engineering, Jaya Prakash Narayan College of Engineering, Mahabubnagar, Telangana, India*
[h]*Department of Computer Science and Engineering, BVRIT Hyderabad College of Engineering for Women, Hyderabad – 500090, India*
[#]**Corresponding authors email yrameswarareddy.mech@jntua.ac.in, gunisettyrama@gmail.com*
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Heat transfer innovation is essential in modern society because thermal management systems need effective heating and cooling processes. It is also an essential component in the vehicle industry and other types of transportation, in addition to automobile industry, aviation technology, the computer industry, and the manufacturing industry. By the inspiration of importance of magnetohydrodynamic hybrid nanofluid over a stretching cylinder with the influence of Williamson fluid and porous medium is examined in this current study. To convert the PDEs into ODEs, suitable self-similarity transformation is used. After applying transformations, for graphical purpose we have used the bvp5c technique. The impact of active parameters affecting the fluid's capacity to transfer significance is demonstrated in graphs and tables. In the result section we noticed on the velocity outlines decreased for increasing M parameter. The Cf and Nu increased for larger values of the M and curvature parameters. Additional properties of M and Rd parameter inputs result in improved temperature profiles.
Keywords: *Williamson fluid; MHD; Porous medium; Heat source; Hybrid nanofluids*
PACS: 44.05.+e, 44.30.+v, 44.40.+a, 47.10.ad.

1. INTRODUCTION

Researchers have shown a great deal of interest in tiny fluids due to the fact that they are able to generate a significant amount of heat in a variety of contemporary and industrial applications. Water, gasoline, and automotive oils are examples of basic functioning liquids that have limited warm displays, which limit their employment in innovative chilling appeals. Other examples include heating oil and motor oil. As a case study, tiny fluids are composed of tiny particles such as aluminium oxide, the metal copper, iron oxides, nanotubes made of carbon carbides, and nitric oxide These small particles enhance the thermal resistance of base fluids. Such tiny fluids possess a wide range of applications in modern systems, including, but not limited to, heating and cooling, hybrid-powered motors, sunlight-based tissues, chemotherapy for cancer, and the development of novel fuels, delivery of medications, and drugs. Choi [1] was the one who made the most significant contribution to the field of nanofluid design, which resulted in changed behaviours. Many studies into the development of tiny fluids have been carried out as a result of the various applications made of nanofluids. Researchers in the fields of applied mathematics and engineering have recently shown a large amount of interest in non-Newtonian fluid mechanics as a result of contemporary advances in technology [2][3][4]. A number of disciplines, including biological sciences, drugs, and chemistry, place a significant amount of significance on the motion and heat transfer characteristics associated with these fluids. Standard approaches cannot correctly explain non-Newtonian liquids' shearing dimension, typical stress variation, and viscoelastic properties due to underlying nonlinear stress-strain rate connections. The complicated dynamics of fluids that are not Newtonian, which includes elastomeric fluids, necessitates the development of accurate forecasting frameworks. These kinds of fluids play an important role in a wide variety of settings [5][6][7].

A mixed nanofluid is an improved version of regular tiny fluids that has enhanced heat transfer, thermophysical properties, and elasticity. In order to achieve the production of a mixed nanofluid, several tiny particles are combined with a base fluid in order to achieve a beneficial interaction that results in increased thermal characteristics. In order to ensure that the heat exchanger's heating and cooling operation was carried out effectively, the performance of a nanofluid hybrid was used. In addition, the application of nanofluid mixtures may be associated with the production of thermal conversion, cooling, technological coolants, and cars. When compared to other nanofluids, hybrid nanofluids are often more difficult to

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generate and required for more sophisticated character development procedures in order to comprehend the characteristics of the various nanoparticles as well as how they communicate with one another [8][9][10][11].

Magnetohydrodynamics, often known as MHD, is a branch of study that examines the interaction among magnetic fields and speed forces in liquids that conduct electricity, such as plasma-based solutions, minerals, and metals that are liquid. Hartmann [12] was the first person to suggest the idea of producing regular magnetic forces inside a fluid with electrolytes, which is considered to be the foundation for magnetically induced dissipation (MHD) investigation. In its most basic form, MHD is used to examine the behavior of substances that conduct electricity. For technical and medicinal purposes, MHD liquids have a wide range of uses. MHD barrier layer fluctuations exert a pulling force on liquids that transmit electricity thanks to their magnetic properties. The enforced MHD results in the generation of a drag force, which is known as the Lorentz force, which acts towards the perimeter of the motion. A wide variety of fluid circulation simulations have been seen to include MHD, which has uses in pharmaceutical manufacturing, producing electricity, and other areas. Radiation has a considerable influence on thermal boundaries, particularly in highly heated processes that are used in engineering fields. Because the result is dependent on the pace of the cooling process, the function that heat conduction plays in achieving the intended output is important [13][14].

According to the current literature, the simultaneous effects of MHD, porous medium, Williamson hybrid nanofluid flow over a stretching cylinder has been illustrated and which all are taken into the model, as per the author knowledge this kind of model have not been examined before. Equations in the form of PDEs are generated as a result of this process. In order to change PDEs into ODEs, the appropriate self-similarity conversion must be performed. After applying transformations, for graphical purpose we have used the numerical method that is bvp5c scheme. In the results and discussion section, graphs for different physical significance are given. Hybrid nanofluid with Ag-Go and kerosine oil enhances solar thermal efficiency. Applications include concentrated automobile, thermal collectors, and lubrication in solar tracking. Therefore, the use of a combination of tiny fluids as traditional cooling agents may serve to enhance the entire heat transfer performance of an automotive system.

2. MATHEMATICAL MODELING

- A steady, incompressible hybrid nanofluid with the presence of magnetic field along a permeable stretched cylinder of radius a is scrutinized.
- The hybrid nanofluid is assumed to flow in the axial x-direction while normal to x is the r-coordinate as illustrated in Fig. 1.
- The deformable (stretching or shrinking) cylinder has a linear velocity $U_w(x)$ with constant characteristic velocity u_0 such that $U_w(x) = u_0 x/L$.
- $v_w(r)$ is the constant mass flux velocity where $v_w(r) > 0$ represents injection or fluid removal and $v_w(r) < 0$ stands for suction.

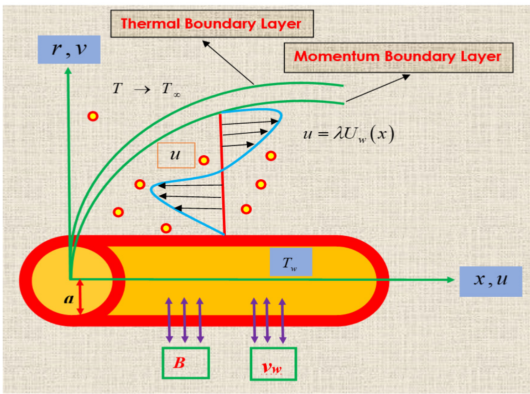

Figure 1. Flow justification of the model.

The mathematical flow equations are constructed as [15][16][17][18].

$$\frac{\partial u}{\partial x} + \frac{\partial u}{\partial r} = 0, \tag{1}$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial r} = \frac{\mu_{hnf}}{\rho_{hnf}}\left(\frac{\partial^2 u}{\partial r^2} + \frac{1}{r}\frac{\partial u}{\partial r} + \sqrt{2}\Gamma\frac{\partial u}{\partial r}\frac{\partial^2 u}{\partial r^2} + \frac{\Gamma}{r\sqrt{2}}\left(\frac{\partial u}{\partial r}\right)^2\right) - \frac{\mu_{hnf}}{\rho_{hnf}}\frac{u}{K^*} - \frac{\sigma_{hnf}}{\rho_{hnf}}\left(B^2 u\right), \tag{2}$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial r} = \frac{k_{hnf}}{(\rho c_p)_{hnf}}\left(\frac{\partial^2 T}{\partial r^2}\right) + \frac{\mu_{hnf}}{(\rho c_p)_{hnf}}\left(1 + \frac{\Gamma}{\sqrt{2}}\left(\frac{\partial u}{\partial r}\right)\right)\left(\frac{\partial u}{\partial r}\right)^2 + \frac{Q_0}{(\rho c_p)_{hnf}}(T - T_\infty) + \frac{\sigma_{hnf}}{(\rho c_p)_{hnf}}B^2 u^2. \tag{3}$$

Along with the boundary conditions are [15]

$$\begin{array}{ll} v = v_w(r),\ u = \lambda U_w(x),\ T = T_w(x), & at\quad r = a \\ u \to 0,\quad T \to T_\infty, & as\ \ r \to \infty \end{array} \tag{4}$$

where the velocities along x and r - axes are denoted by u and v, accordingly and T is the Hnf temperature. The ambient temperature T_∞ is constant and the variable wall temperature is considered as $T_w = T_\infty + T_0\left(x/L\right)^2$, where T_0 is the characteristic temperature. λ means the constant parameter of shrinking $(\lambda < 0)$ or stretching $(\lambda > 0)$ parameters while $(\lambda = 0)$ symbolizes the static cylinder.

The following suitable self-similarity transformations are defined as:

$$u = \frac{u_0 x}{L}F'(\eta),\quad v = -\frac{a}{r}\sqrt{\frac{u_o\upsilon_f}{L}}F(\eta),\ \theta(\eta) = \frac{T - T_\infty}{T_w - T_\infty},\ \eta = \sqrt{\frac{u_o}{\upsilon_f L}}\frac{r^2 - a^2}{2a}, \tag{5}$$

So that

$$v_w(r) = -\frac{a}{r}\sqrt{\frac{u_o\upsilon_f}{L}}S. \tag{6}$$

The following is a list of the thermophysical characteristics of Hnf:

$$Q_1 = \frac{\mu_{hnf}}{\mu_f}, Q_2 = \frac{\rho_{hnf}}{\rho_f}, Q_3 = \frac{(\rho c_p)_{hnf}}{(\rho c_p)_f}, Q_4 = \frac{k_{hnf}}{k_f}, Q_5 = \frac{\sigma_{hnf}}{\sigma_f}.$$

In order to create the following dimensionless ODEs, Eqs. (2) to (4) are transformed using the ideal technique indicated in Eqs. (5 and 6).

$$\begin{array}{l} \frac{Q_1}{Q_2}\left((1+2\gamma\eta)F''' + 2\gamma F''\right) + \frac{Q_1}{Q_2}\left[\frac{3}{2}\gamma(1+2\gamma\eta)^{1/2}WeF''^2 + We(1+2\gamma\eta)^{3/2}F''F'''\right] \\ +FF'' - (F')^2 - \frac{Q_1}{Q_2}KF' - \frac{Q_5}{Q_2}MF' = 0, \end{array} \tag{7}$$

$$\begin{array}{l} \frac{1}{Pr}\frac{Q_5}{Q_2}\left((1+2\gamma\eta)\theta'' + 2\gamma\theta'\right) + \frac{Q_1}{Q_3}Ec\left[\left(1 + WeF''(1+2\gamma\eta)^{1/2}\right)\right]F''^2(1+2\gamma\eta) + F\theta' - 2F'\theta \\ +\frac{Q\theta}{Q_3} + \frac{Q_5}{Q_3}EcM(F')^2 = 0. \end{array} \tag{8}$$

The boundaries of the change are described as:

$$\begin{array}{l} f(0) = S,\ f'(0) = \lambda,\ \theta(0) = 1 \\ f'(\infty) = 0,\ \theta'(\infty) = 0. \end{array} \tag{9}$$

Note that $M = \frac{\sigma_f B^2 L}{\rho_f u_0}$ Magnetic field parameter, $Pr = \frac{\mu_f (c_p)_f}{k_f}$ Prandtl number, $\gamma = \sqrt{\frac{\upsilon_f L}{u_o a^2}}$ is the Curvature parameter, $Ec = \frac{u_w^2}{c_p(T_w - T_\infty)}$ is the Eckert number, $K = \frac{\upsilon_f L}{aK^*}$ is the porosity parameter, and $Q = \frac{Q_0 L}{\upsilon_f(\rho C_p)_f}$ dimensional heat generation/absorption, $We = \sqrt{\frac{2u_o}{\upsilon_f L}}\frac{u_0 x}{L}\Gamma$ is Weissenberg number.

The dimensional form of C_f and Nu_r are given by

$$C_f = \frac{\mu_{hnf}}{\rho_f U_w^2}\left(\frac{\partial u}{\partial r}\right)_{r=0},\ Nu_x = \frac{xk_{hnf}}{k_f(T_w - T_\infty)}\left(-\frac{\partial T}{\partial r}\right)_{r=a}, \tag{10}$$

The non-dimensional form of Eq. (11) converted is

$$Re_x^{1/2} C_f = Cf = Q_1 f''(0), \;\; Re_x^{-1/2} Nu_x = Nu = -Q_4 \theta'(0). \tag{11}$$

Where Re_x is the local Reynolds number.

3. SOLUTION METHODOLOGY

The nature of the ODE system (7–8) with BCs (9) is extremely nonlinear in its characteristics. For the purpose of dealing with these equations, we adopt a computational approach known as the bvp5c method. Using MATLAB solver, we are able to solve the control problem. The midway method's standard operating procedure is laid out in detail below (Fig. 2).

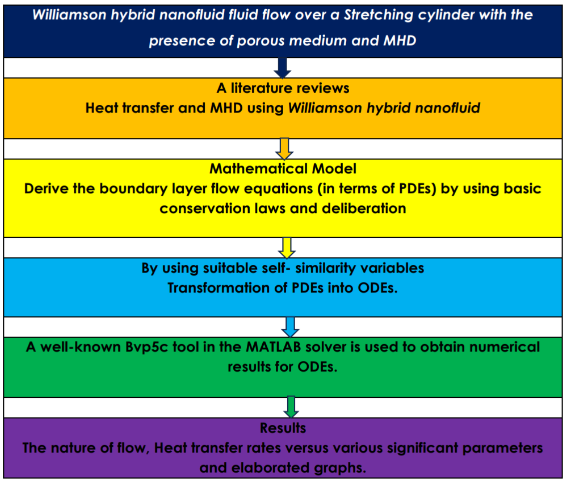

Figure 2. Flow chart of the present investigation problem.

4. RESULTS AND DISCUSSION

In order to describe the behavior of the Williamson hybrid nanofluid flow over a Stretching Cylinder, along with the bvp5c process in MATLAB solver were used in this investigation phase. The properties of hybrid nanofluid are presented in Table 1, as well as validation of comparison results are demonstrated in Table 2.

Table 1. Thermophysical properties of base fluid and hybrid nanofluids[19].

Property	Kerosene Oil	Ag	Go
Density $\rho\ (kgm^{-3})$	783	10,500	1800
Specific heat $C_p\ (Jkg^{-1}K^{-1})$	2090	235	717
Heat conductivity $k_f\ (Wm^{-1}K^{-1})$	0.145	429	5000
Electrical conductivity $\sigma\ (\Omega m)^{-1}$	21×10^{-6}	63×10^{-6}	6.30×10^{7}

Table 2. The quantitative results of the skin friction coefficient of different of values for ϕ_2 by fixing parameter values $S=\gamma=M=Ec=0$, and $Pr=21$, $\phi_1=0.01$, $\lambda=1$.

ϕ_2	**Najiyah et al.** [15]	**Present results**
0.005	-1.327098	-1.3270827
0.02	-1.409490	-1.4094721
0.04	-1.520721	-1.5207003
0.06	-1.634119	-1.6341005

Velocity and temperature profiles shows several flow properties, including the Magnetic field (M), Weissenberg number (We), Porous medium (K), and Q. The velocity profile decreases with increasing M Parameter, as seen in Fig. 3. Magnetic field lead to more confined Lorentz power, which in turn leads to a reduced velocity profile, which is a practical consequence. Understanding that the nanofluid's movement decreases as a consequence of the fact that the fluid's movement in the material is inversely related to viscosity. While the opposite nature we noticed on energy profile which is presented in Fig. 6. The effect of the Weissenberg number We on the velocity profile $f'(\eta)$ it is shown in Fig. 4. The force boundary layer of the Williamson nanofluid shrinks for higher values of the We. From a physical standpoint, we are aware that We represents the proportion of time spent relaxing to time spent calculating. A decrease in velocity is the result of a longer processing period, which is caused by an increase in the number of We. While the reverse trend we observed on energy profile, which is demonstrated in Fig. 7. The effect of the K on the $f'(\eta)$ is apparent in Fig. 5. It is shown that the velocity outline declines with increasing K parameter, which is in tune with reality. Furthermore, when we the trip away from the border, as far the liquid movement is concerned, the porous nature of the border is insignificant. Fig. 8 represents the impact of Q on energy outline. For the larger values of the Q in energy profile increased. Physically, when heat generation rises, so does the inherent energy of liquid particles, resulting in a rise in the temperature outline.

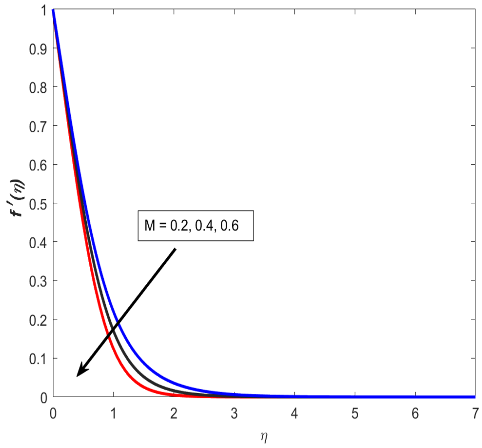

Figure 3. Influence of M on $f'(\eta)$

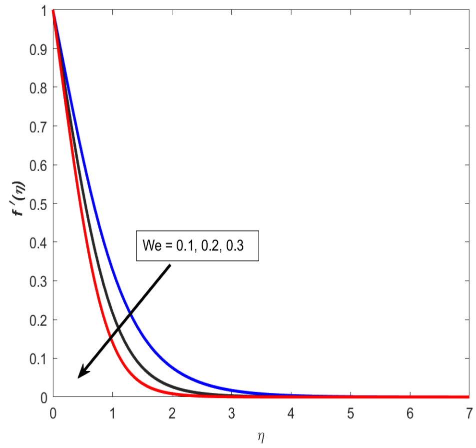

Figure 4. Impact of We on $f'(\eta)$

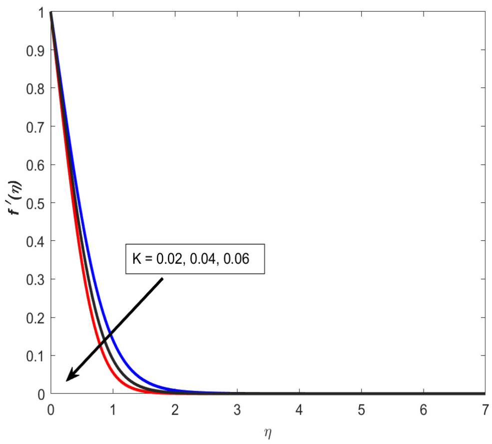

Figure 5. Impact of K on $f'(\eta)$

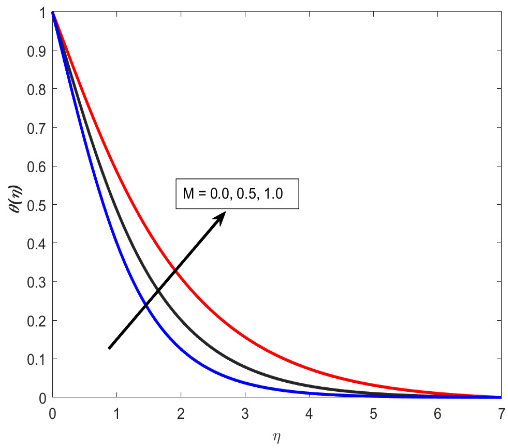

Figure 6. Impact of M on $\theta(\eta)$

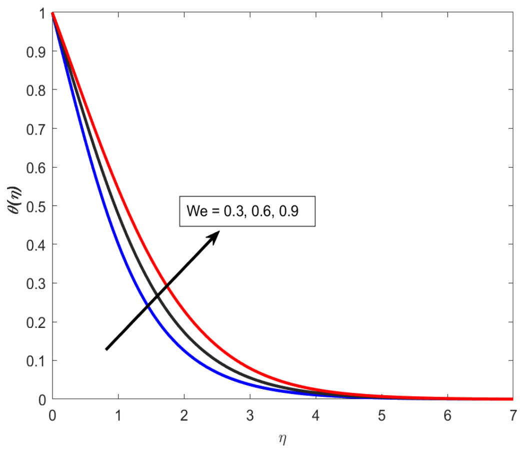

Figure 7. Impact of We on $\theta(\eta)$

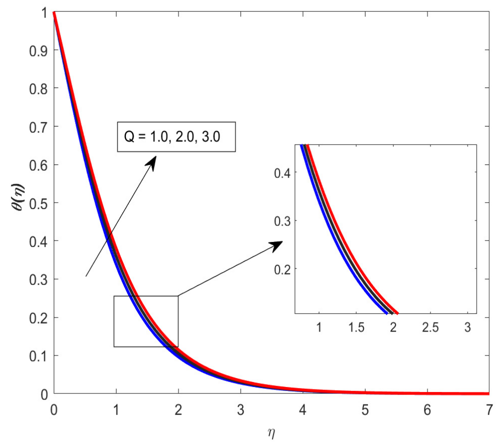

Figure 8. Impact of Q on $\theta(\eta)$

The effect of M and K on Cf outline is demonstrated in Fig. 9. For the higher values of the M on the Cf profile decreased, due to the physical phenomenon of lot of Lorentz force is applied on the fluid movement so that's why the profile decreased. The impact of M and Rd parameters on Nu outline is presented in Fig. 10. For the larger values of the magnetic field the Nu profile increased. From a physical point of view, here the Lorentz force is act as an electric nature and this force is mixed with the fluid movement so that's why the profile enhanced.

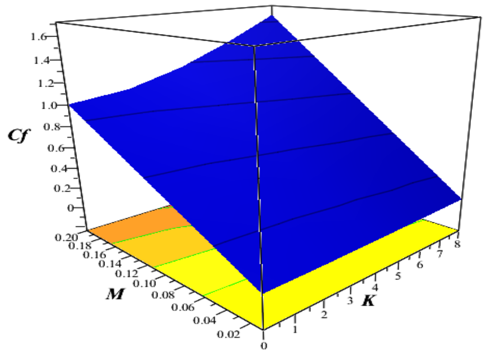

Figure 9. Impact of M *and* K on Cf

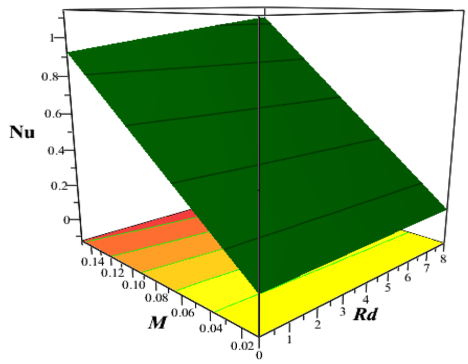

Figure 10. Impact of M *and* Rd on Nu

Streamlines profiles

Streamlines, the investigation of fluid behavior and the portrayal of flow, in particular, provide a range of qualities that, when taken into account together, allow them to be excellent tools for analyzing and conducting research on the movements of fluids. This is particularly true when used to the investigation of fluid movement. Figs. 11 and 12 exhibit magnetic parameter for various values of M= 0.3, 0.5 influences on streamlines plots. Magnetic parameter strength draws electrical conductivity molecules more towards to the main stream.

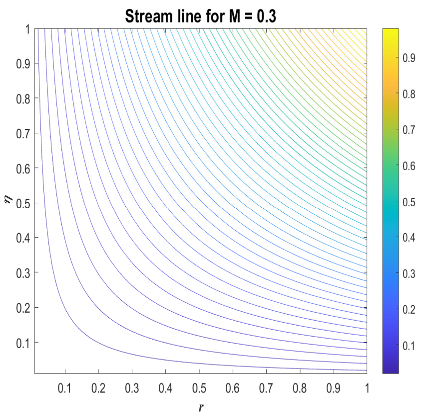

Figure 11. Stream lines for $M=0.3$

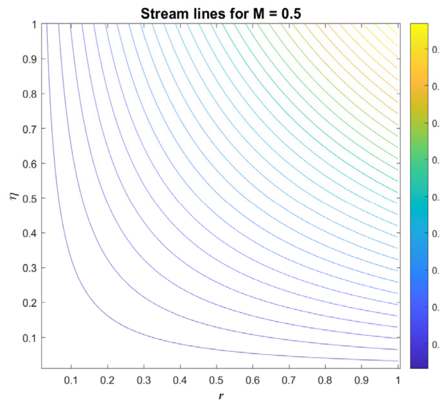

Figure 12. Stream lines for M=0.5

5. CONCLUSIONS

The current examination work explored the numerical solution for MHD of *Ag-Go* hybrid nanofluid over a Stretching Cylinder. The bvp5c technique was used to solve the issue of velocity, temperature and the outcome was truly the solution to the problem. And also, in order to demonstrate the impact of important parameters graphs are generated. The results are presented in a variety of graphical formats, including a 2D plots, 3D plots, and streamlines.
The following list includes the study's noteworthy results:

- Velocity profile declines for the higher values of the M parameter on the other hand we noticed the opposite tendency in energy profile.
- Velocity outline decreased for the larger values of the We parameter.
- Increasing the radiation parameter enhanced the temperature profile.
- The skin friction factor decreases for the higher values of the porous and magnetic parameter.
- The Nusselt number profile enhanced, for the higher values of the M and Rd.
- Streamlines have an oscillating character, which is necessary for magnifying the various values of nanoparticles volume fractions.

ORCID
Gunisetty Ramasekhar, https://orcid.org/0000-0002-3256-3145; **Sangapatnam Suneetha,** https://orcid.org/0000-0001-6627-6446
Shaik Jakeer, https://orcid.org/0000-0002-6350-1457; **Seethi Reddy Reddisekhar Reddy,** https://orcid.org/0000-0001-5501-570X

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НОВА ТЕНДЕНЦІЯ АВТОМОБІЛЬНИХ АСПЕКТІВ МГД ПОТОКУ ГІБРИДНОЇ НАНОРІДИНИ ЧЕРЕЗ ПОРИСТИЙ ЦИЛІНДР ЩО РОЗТЯГУЄТЬСЯ: ЧИСЛІВЕ ДОСЛІДЖЕННЯ

Гунісетті Рамасекхар[a], Ю. Рамешвара Редді[b], Сура Шрінівасулу[c], Шайк Джакір[d], Сітхі Редді Реддісекхар Редді[e], Сангапатнам Сунітха[f], Т. Адітья Саї Шрінівас[g], Ашок Сарабу[h]
[a]*Факультет математики Меморіального інженерно-технологічного коледжу Раджива Ганді (автономний), Нандьял 518501, Андхра-Прадеш, Індія*
[b]*Факультет машинобудування, JNTUACE, Пулівендула 516390, Андхра-Прадеш, Індія*
[c]*Факультет хімії, Інженерний коледж SVR, Айялуру Мета, Нандьял 518501, Андхра-Прадеш, Індія*
[d]*Школа технологій, Університет Аполло, Чіттур, Андхра-Прадеш 517127, Індія*
[e]*Департамент математики, Освітній фонд Конера Лакшмайї, Борампет, Хайдарабад, Телангана 500043, Індія*
[f]*Факультет прикладної математики Університету Йоги Вемана Кадана 516003, Андхра-Прадеш, Індія*
[g] *Факультет комп'ютерних наук та інженерії, Інженерний коледж Джая Пракаш Нараян, Махабубнагар, Телангана, Індія*
[h]*Факультет комп'ютерних наук та інженерії, Хайдарабадський інженерний жіночий коледж BVRIT, Хайдарабад, Індія*

Інновації в галузі теплопередачі мають важливе значення в сучасному суспільстві, оскільки системи управління температурним режимом потребують ефективних процесів нагрівання та охолодження. Вони також є важливим компонентом в автомобільній промисловості та інших видах транспорту, а окрім автомобільної промисловості, в авіаційній техніці, комп'ютерній індустрії та обробній промисловості. У цьому дослідженні розглядається важливість магнітогідродинамічної гібридної нанорідини Вільямсона в циліндрі, що розтягується, і пористого середовища. Для перетворення PDEs в PDEs використовується відповідне перетворення самоподібності. Після застосування перетворень для графічних цілей ми використали техніку bvp5c. Вплив активних параметрів, що впливають на здатність рідини передавати параметри, показано на графіках і таблицях. У розділі результатів ми помітили, що контури швидкості зменшуються зі збільшенням параметра M. Cf і Nu збільшувалися за великих значеннях параметрів M і кривизни. Додаткові властивості вхідних параметрів M та Rd призводять до покращення температурних профілів.
Ключові слова: *рідина Вільямсона; МГД; пористе середовище; джерело тепла; гібридні нанорідини*